Solid Earth

ES-3 The student will demonstrate an understanding of the internal and external dynamics of solid Earth.

ES-3.3 Summarize the theory of plate tectonics (including the role of convection currents, the action at plate boundaries, and the scientific evidence for the theory).
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 8th grade (8-3.6) were introduced to the theory of plate tectonics with the motion of the lithospheric plates and geologic activities at the plate boundaries. Students have not been introduced to the internal driving forces or to the scientific evidence for the theory.

It is essential for students to know the theory of plate tectonics states that Earth's crust and rigid upper mantle are broken into enormous sections called plates. Tectonic plates move in different directions and at different rates over Earth's surface. The plates are continually changing in shape and size.

***Role of Convection Currents**:*
What causes Earth's plates to move is explained in a hypothesis that proposes convection currents within the mantle.
The movement of the plates is driven by the unequal distribution of heat within Earth that set up convection currents within the upper mantle.

- Hot material found deep in the mantle moves slowly upward and serves as one part of Earth's internal convection system.
- Also cooler, denser sections of oceanic lithosphere descend into the mantle, setting the outer crust into motion.
- The asthenosphere, below the lithosphere, is partially melted due to an increase in temperature. (The partial melting is due to increasing temperature without sufficient increase in pressure to prevent melting. Temperatures below the asthenosphere are higher, but material is not melted because pressures are too high to allow it.)
- Convection currents in the asthenosphere are thus set in motion by the transfer of energy between Earth's hot interior and the cooler exterior.

There are still many unanswered questions about mantle convection currents.

***Action at Plate Boundaries**:*
When tectonic plates move, they interact at places called plate boundaries. Each type of boundary has certain geologic characteristics and processes associated with it.

Divergent Boundaries are places where two plates are moving apart (separating).

- Most are found on the sea floor and form ocean ridges.
- The formation of new crust occurs at most divergent boundaries and accounts for high heat flow, volcanic eruptions, and earthquakes.
- On continents when continental crust begins to separate, the stretched crust forms a long, narrow depression called a rift valley.

Convergent Boundaries are places where two plates are moving toward each other. There are three types, which are classified by the type and density of crust involved:

- *Oceanic crust converging with oceanic crust* – one of the two plates becomes denser due to cooling and descends beneath the other in a process called subduction that creates a deep trench and a volcanic arc of islands. The subducted plate descends into the mantle and melts, thus recycling the crustal material.

- *Oceanic crust converging with less dense continental crust* – subduction also occurs but the subduction causes a trench and a mountain range with many volcanoes along the continent's edge.
- *Continental plates collide* – both plates are too buoyant to be subducted, so the colliding edges of the continents are crumpled and uplifted to form a mountain range.

Transform Boundaries are places where two plates slide horizontally past each other.
- At these boundaries crust is only deformed or fractured.
- Most transform boundaries are not found on continents; a famous exception is the San Andreas Fault in southwest California.

***Scientific Evidence for the Theory**:*
Evidence for the plate tectonic theory began with early observations made about the shape of the continents. A *continental drift hypothesis* was developed. Evidence for this hypothesis included similar rock types and formations on continents now separated, as well as similar fossils of several different animals and plants that once lived on land now found to be widely separated continents. That hypothesis was originally rejected because the force great enough to move continents could not be shown but as more evidence was gathered, it was revisited and leads to today's *plate tectonics theory*.

In the 1960s evidence was found on the seafloor that could explain how continents move.
- *Seafloor spreading* is a theory stating that new ocean crust is formed at ocean ridges where magma rises to the surface and hardens.
  - A new section of crust forms which slowly moves away from the ridge.
  - Crust is destroyed, re-melted, at deep-sea trenches.
- *Magnetic striping* patterns emerged as scientists collected data about the areas parallel to the ocean ridges.
  - The magnetic pattern on one side of the ridge matched the pattern on the other.
  - Scientists were able to determine the age of the ocean floor from the magnetic recording.
  - Relatively new ocean floor crust is found near ocean ridges,
  - and older ocean crust is found along deep-sea trenches.

TEACHER NOTE: Even though it is not specifically stated in the indicator, a knowledge of some of the major plates, their locations, and relative motion helps students to identify plate boundaries and the formations and activities that are evident along the plate boundary in that region of Earth.

It is not essential for students to know the explorations that took place to acquire the information for the theory of plate tectonics.

Assessment Guidelines:
The objective of this indicator is to *summarize* major points about the theory of plate tectonics; therefore, the primary focus of assessment should be to generalize major points about the role of convection currents, the actions at plate boundaries, and evidence for the theory.
In addition to *summarize* appropriate assessments may require students to:
- *compare* the actions at the various plate boundaries;
- *illustrate* with drawings or diagrams the geologic characteristics and processes at plate boundaries;
- *recall* evidence from the early continental drift hypothesis.